The Road Design Considering Traffic Safety at Continual Tunnel Section

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ABSTRACT

There are various elements which affect drivers' safety. The elements can be divided into geometric elements (including horizontal alignment and vertical alignment etc), drivers' characteristics elements (including rivers' mental state, and steering behavior etc) and external elements etc (including variation of meteorological environment). However, general road design has a great notion that only geometric and structural safety. This report suggests comfortable and safe road design model for users not only by modifying geometrical structure to enhance drivers' safety but also by applying traffic safety facilities through various detailed analyses on the road extension work between Damyang and Seongsan of the highway No. 12(Section No. 12) where continual tunnel and downgrade section is inevitably occurred.

1. An introduction

1.1 Background and objective

Generally, tunnel section has advantages of good horizontal and vertical alignment and natural conservation better than detour of mountain. Korean road routes where exist many mountain areas continually seek to have long and continual tunnel to be environment friendly and enhance level of service quality. Advantages to construct tunnel must be evaluated with driver's safety. When drivers pass tunnel, there are potential dangerous elements because of driver's mental state (including lower illumination during day driving, narrow shoulder, driver's sense of isolation and etc). In addition, alignment selection is very limited at tunnel which is located in mountain area, and tunnel section has the most possibility to car accident than others because of the direct sunray effect, various weather and climate condition. Therefore this study aims to decide the optimum geometric alignment. Driver's behavior, visual trouble and etc is analyzed as the direct sunray effect, weather and climate and dangerous section is derived by it's analysis and excluded dangerous elements. This study intends to prevent car accident by planning safety treatment. And objective of this study is deriving smooth traffic flow and driver's safe insurance plan through above deciding elements.

Damyang and Seongsan of the highway No. 12(Section No. 12) is selected to verify this study. This section with existing dual carriageway 2 lanes, and going through mountain area has had many heavy accidents because of poor geometry. Therefore, new route plan is to actively meet adjacent traffic system's variation, expand road system according to region development, and balance country's development. Considering function, economical efficiency, environmental mitigation and minimizing popular complaints of highway through mountain area, the most suitable route was selected (Figure. 1, Table 1). This study is done about selected route which have continuous tunnel in relative short length.

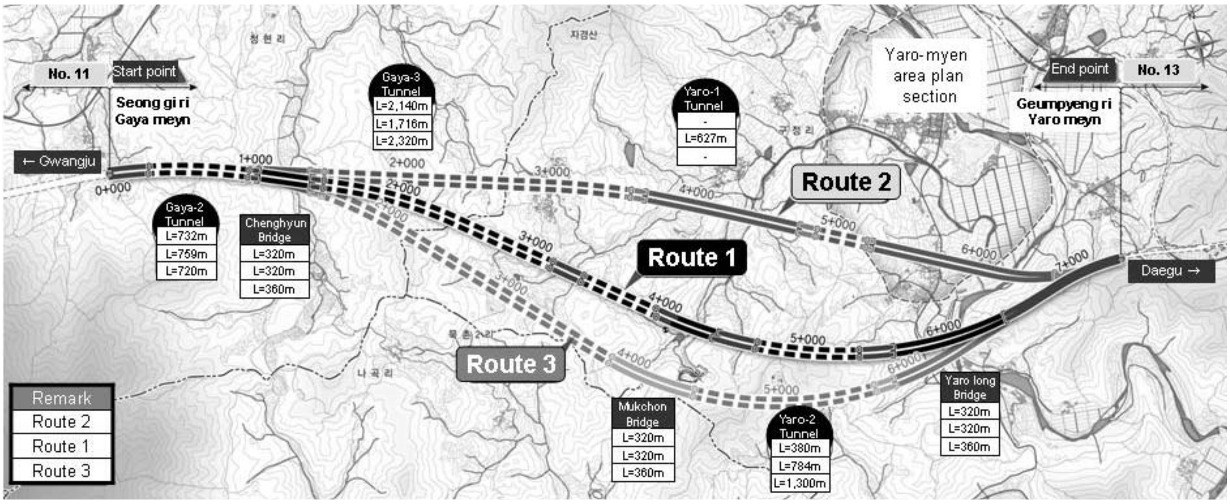


Figure 1. Comparison of route 1,2,3

Table 1. Route 1,2,3 comparing

Design Elements	Route 1	Route 2	Route 3
Length	·L=7.34km	·L=7.06km	·L=7.60km
Minimum radius	·R=2,300m	·R=1,200m	·R=2,350m
Maximum slope	·S=2.95%	·S=2.95%	·S=2.95%
Bridge	·3 bridges/1,383m	·3bridges/2,640m (△1,257m)	·2bridges/1,200m (▽183m)
Tunnel	·4 tunnels/3,883m	·3tunnels/3,252m (▽631m)	·3tunnels/4,340m (△457m)
Construction Cost	·255.8 billion won (considering escalation)	·302 billion won (△46.2 billion won)	·260 billion won (△4.2 billion won)
Feature	·Detour Yaro-myeon area plan ·Go though mountain area by structure(bridge and tunnel) ·Normal length ·Long tunnel (Gaya 3 tunnel L=1,716m) ·High level pier as valley passing	·Conflict Yaro-myeon area plan ·Go though mountain area by structure(bridge and tunnel) ·Minimum length ·Length of Gaya-3 tunnel has longer than other routes (L=2,140m) ·Length of Mukchon bridge(L=1,060m) and Yaro grand bridge(L=1,260m) has longer than other routes	·Detour Yaro-myeon area plan ·Reason to going through mountain, backfill construction instead of Mukchon bridge ·Longest length than other routes ·Length of tunnel has longer than other routes and this route has long tunnel(Gaya-3 tunnel L=2,320m) ·Minimum length of bridge
Choice	◎		

1.2 Scope and method of this study

1.1.1 Scope of this study

The section of this study has continual tunnels (Gaya-2, Gaya-3, Yaro-3 and Yaro-2 tunnel). The scope of this study do literature review about feature of traffic flow around tunnel to guarantee driver's safety and set up solutions by analyzing section's climate and weather to protect drivers from the direct sunray effect, freezing, fog and etc.

Scope of space: Seong-gi Ri, Ga-ya Myeon, Hab-cheon Gun, Kyoung-sang Namdo
(Geum-pyeong Ri, Yaro Myeon)

Scope of study:

- Analysis of Tunnel's traffic flow by literature review
- Alignment and bridge plan considering driving safety
- Possibility of freezing and hazard in entrance and exit of tunnel
- Analysis of the direct sunray effect when driver enter and exit the tunnel
- Analysis of visibility range reduction by fog
- Planning suitable safety facility

1.2.2 Method of the study

At first, this study modifies input data (velocity change and driver's mental state) by literature review and its data is applied and this study analyzes driver's characteristic and traffic flow when passing the section of this study to examine suitability of alignment.

This study collects and analyzes local weather observatory data to reflect local characters in deriving dangerous section by weather analysis.

On this occasion, to derive not qualitative output by only weather and climate character but quantitative output, this study uses numerical solution based on 3-dimension which is geographic, structural and weather's character. By above methods, it ensures reliability. Considering economic and efficiency, this study plans safety facility in dangerous sections to ensure driver's safety.

2, Literature review

2.1 Traffic flow character in tunnel section

Normal driver experiences natural delay (Bottle Neck) when accesses to tunnel section by reducing capacity and velocity because of reducing road-side space and psychological elements of driver.

Reasons which cause reducing velocity and capacity are following elements:

- Driver will be nervous because of seeing as if black hole just in front of tunnel entrance
- Instantly incomplete acquiring needed information to drive because of delaying adoption of light and darkness when entering or exiting tunnel.
- Driver becomes psychologically uneasy condition because closing space induces oppressive and closed feeling to driver
- Change surrounding visual intensity of illumination by installing illuminator in regular distance
- Shoulder width, front field of vision, road-side space is narrower than bright opening section and it makes driver receive stress.

Korean road traffic authority (1997) reported that traffic velocity gradually reduces before tunnel entrance and is the lowest at 40m after entering tunnel and gradually increases after 100m from tunnel entrance. In continual tunnel section which repeats crossing lighting and darkness, driver doesn't have enough time to adopt and driver has psychological shadow. It is analyzed negatively effecting driver.

2.2. Analysis of car accident

2.2.1 Status of accident in tunnel section

The result of analyzing car accident in tunnel describes that total car accident reduced but car accident increased in tunnel. The proportion of accident in tunnel to total accident is increased from 0.188% during year 2003 to 0.235% during year 2007.

Derived results in analysis of accident rate for general section describe that the accident rate of tunnel section is higher than that of basic freeway section when V/C is above 0.67. [1]

Table 2. Number of car accident in tunnel / Total number of car accident

Type	2003 yr	2004 yr	2005 yr	2006 yr	2007 yr
Total number of car accident	240,832	220,755	214,171	213,745	211,662
Number of car accident in tunnel	453	382	549	567	497
Proportion of accident in tunnel to total accident	0.188	0.173	0.256	0.265	0.235

* Note: The statistics of Road traffic authority in Korea

2.2.2 The status of car accident in weather condition

The result to analyze car accident of various weather condition indicates that accident's fatality rate in fog weather is the highest (11.27%). And it indicates that heavy accident occurred by restricting driver's visual distance.

The result of analyzing car accident of various road surface condition indicates that accident's fatality rate on freezing and moisture road surface is 4.00% and 4.07% respectively and it is higher than drying road surface.

The statistics indicate that when road route plan, route choice and safety facility plan are important through danger analysis of weather condition and road surface condition.

Table 3. Status of car accident classified by weather condition (average from 1998 to 2005)

Type	Sunny	Cloud	Rain	Fog	Snow
Total number of car accident	212,548.1	13,183.5	18,092.6	610.38	2,061.8
Fatality [persons]	6,562.1	567.5	725.9	68.8	69.4
Fatality rate[%]	3.09	4.3	4.01	11.27	3.37

* Note: Statistical yearbook of Korea express corporation 1998~2005

Table 4. Status of car accident classified by road surface condition (average from 2000 to 2004)

Type	Dry	Moist	Freezing	Drifted snow
Total number of car accident	218,775.8	24,325	2,283.6	1,622.4
Fatality [persons]	6,681.2	973	93	47.4
Fatality rate[%]	3.05	4.00	4.07	2.92

* Note: Statistical yearbook of Korea express corporation 2000~2004

3. To ensure driver safety by road route plan

3.1 Examine drive safety

3.1.1 Plan of geometry

Road's geometric feature influences driver, and geometric feature is one of the important elements. Combination of physical element and driver's psychological element makes driver's behavior which is reflected in geometric feature.

The section of this study is organized as continual tunnel so driver is exposed by geometrical effect in tunnel, it reduce traffic capacity and can induce accident by reducing traffic ability. This study executes optimum geometric process for driver going through tunnel section.

- Improving vertical alignment of downgrade
- Ensuring illuminative adaptation distance and alignment consistency (a straight line) at tunnel entrance and exit (Gaya-2, Yaro-1 tunnel) [2], [3], [4]
- Giving driver opening feeling by widened tunnel entrance and exit (up/down line 1.0m) when enter or exit tunnel

Table 5. Improvement of vertical alignment

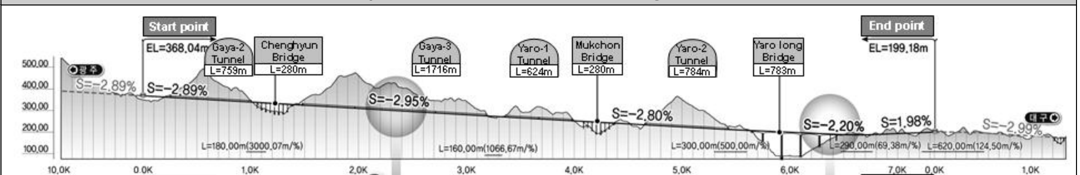
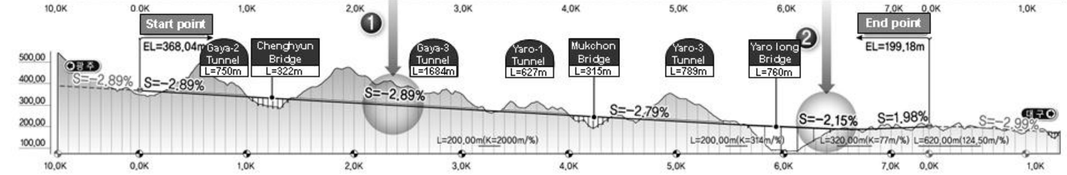
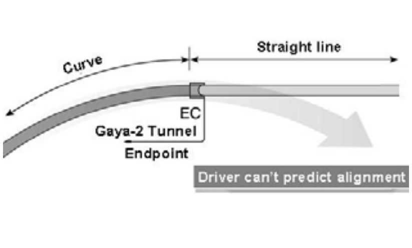
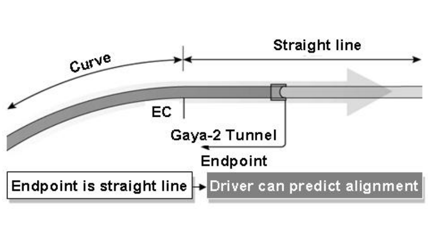
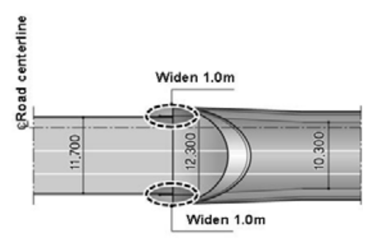
Type	Improvement of vertical alignment
Original design	
Alternative design	

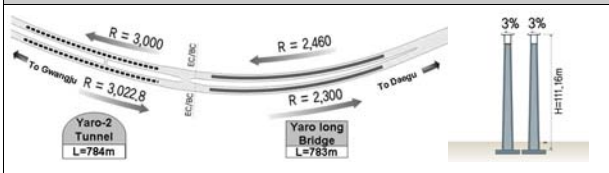
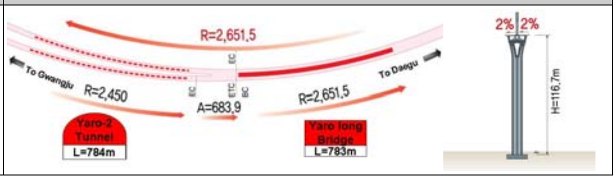
Table 6. Improvement of horizontal alignment and tunnel exit and widened tunnel entrance

Improvement of horizontal alignment		Widened tunnel entrance
Original design	Alternative design	
		

3.1.2 Yaro grand bridge plan near Yaro 2 Tunnel

Yaro 2 tunnel and Yaro grand bridge are adjacently planed each other in curve section, so alignment and type of bridge affect the drivers when entering and leaving tunnel. The original design has two separated sections and composite curve that tunnel and bridge section has 3,000m and 2,460m of curve radius respectively. The alternative design has a single section(R=2,651.5m) to ensure alignment consistency and superelevation keep up 2% at Yaro grand bridge to enhance workability and driving performance, which ensures drivers stable (Table 7).

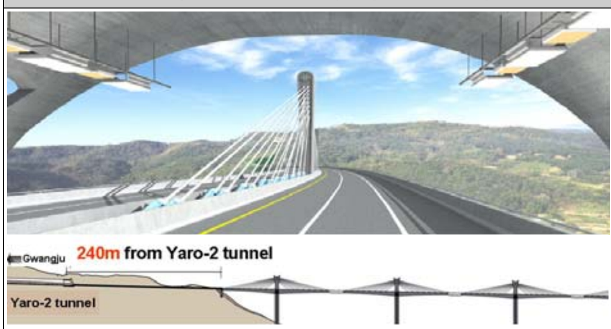
Table 7. Geometric improvement at Yaro grand bridge

Original design	Alternative design
	

Yaro grand bridge was initially designed as box girder bridge with 175m main span, but there are possibilities of contact with Gaya stream, which makes deflection of the bridge and is not environmentally friendly, so alternative design with the main span over 190m has been considered. Finally, extradosed bridge design which has strength in curve alignment, a single pier of up-down direction, landscape, operation & maintenance, environment has been selected.

And then plan of 4 towers strongly has complicated feeling and the result of sight distance analysis when driver exit Yaro 2 tunnel indicate driver's sight is excessively blocked by cables and first tower so it induce that driver has a feeling of uneasiness. But plan of 2 towers has good sight distance because the first tower is somewhat apart from tunnel exit and landscape at lower part and at travelling is beautiful, so the extradosed bridge with 2 towers is selected as alternative design.

Table 8. Comparison between the vision of 4 towers and 2 towers

Comparative design (4 Towers)	Alternative design(2 Towers)
	

3.2 Result of alignment analysis

3.2.1 Travelling consistency analysis by speed profile model

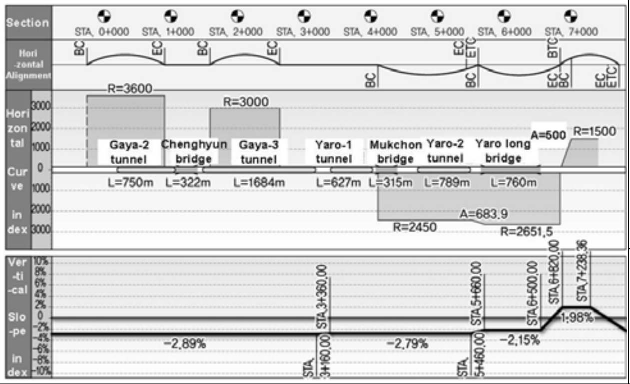
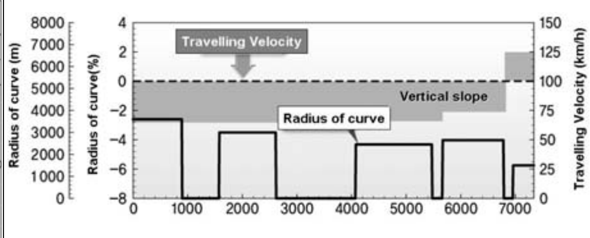
Result of harmony analysis of horizontal and vertical alignment according to geometric design in three dimensions to geometric design in study's section indicates ensuring visual continuance.

In order to evaluate design safety depending on geometric design, travelling consistency is analyzed using DCM(Design Consistency Module) of IHSDM(Interactive Highway Safety Design Model) 2008 V5.0 which is developed by U.S. department of transportation and can evaluate V85 expecting speed, free flow, passenger car unit. The result (refer to Table 9) indicates that average travelling speed is 100km/h and consistency grade is good. (|V85-Vd|=0 ＜10). Therefore improvement alignment enhances the safety of driver.

Table 9. Travelling consistency standard

Type	Standard 1	Standard 2	Remark
Good	|V85-Vd| ≦ 10[km/h]	|V85i-V85j| ≦ 10[km/h]	•V85: travelling speed •Vd: design speed •V85i: travelling speed at i st •V85j: travelling speed at j st
Fair	10[km/h] < |V85-Vd| ≦ 20[km/h]	10[km/h] < |V85i-V85j| ≦ 20[km/h]	
Poor	20[km/h] < |V85-Vd|	20[km/h] < |V85i-V85j|	

Table 10. Travelling consistency analysis result

<table>
<tr><th>Analysis result of alignment harmony</th><th>Analysis result of travelling consistency</th></tr>
<tr><td rowspan="2">
</td><td>
</td></tr>
<tr><td>• average travelling speed 100km/h
• |V85-Vd|=0 ＜10, good grade</td></tr>
</table>

3.2.2 Analysis of travelling safety

Actual drive-ability is influenced not only by physical element of road geometric but also psychological element. To evaluate travelling safety, this study use SS3D PM (Solar Space 3 Dimension Psychological Module) program which consider driver's psychology and apply psychological engineering elements.

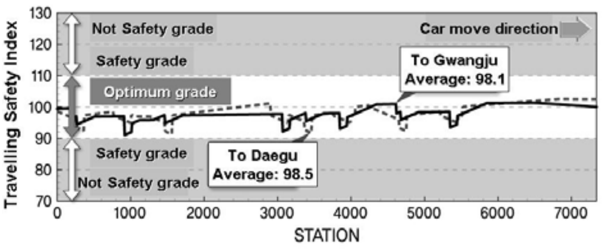
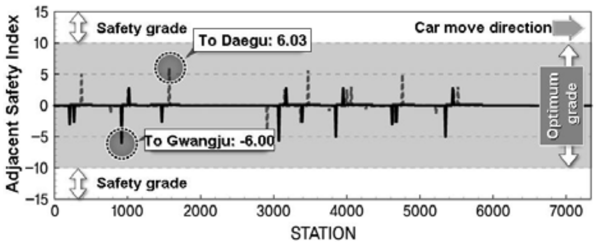
Deriving cone at each position by distance analysis each road direction expect perceptive distance, car speed by road geometric and analyze travelling safety applying revision coefficient of driver's behavior. The result of above process is evaluated by travelling standard (Table 11)

The result of analysis indicate that travelling safety index distribution is maximum 8.94 which is below 10, it is stable grade and also adjacent safety index is maximum 6.03 which in below 10, it is stable grade (Table 12)

Table 11. Standard of safety index

Type	Travelling safety index	Adjacent safety index	Remark
Stable	|Pm-Vd| ≦ 10	|Pmi-Pmj| ≦ 10	•Pm: psychological index •Vd: most suitable index •Pmi: psychological index of i st •Pmj: psychological index of j st
Calm	10 < |Pm-Vd| ≦ 20	10 < |Pmi-Pmj| ≦ 20	
Trouble	20 < |Pm-Vd|	20 < |Pmi-Pmj|	

Table 12. Result of travelling safety analysis

Travelling safety index distribution	Adjacent safety index distribution
	

4. Evaluation of freezing effect

4.1 General

In case of general road and tunnel going through mountain area, sunshine duration can be reduced because cutting slope and ground surrounding geographical feature block the sun. It can make shadow condition at ordinary time. Reduced sunshine duration is the reason of freezing when it rains or snows in winter. If driver don't know information about danger of freezing section, driver can make a large accident by car sliding.

Driver who go through continual tunnel section of this study can't percept opportunity to get information about road surface of tunnel exit. If driver is late to adapt visual circumstance at entrance and exit of tunnel, immediately driver travels with insufficient information about needing travel. And then if tunnel's exit get freeze, driver don't take proper action, which can result in accident. Accordingly this study analyzes dangerous section of freezing and deal with dangerous section grade to ensure safety exposing such danger as following.

4.2 Result of freezing section analysis

Result of analyzing weather data during the last 10 years indicate that average snow days is 7.4 days which is lower than 18.9 days, average of whole country. Average winter temperature is above 0℃, so freezing danger is relatively low. But temperature of snow day is below the freezing point, freezing day is 113.3 days which is relatively many days. Therefore shadow zone is more dangerous when there is snow or water on the road.

Table 13. Feature of climate

Type	Snow day	Snowfall	Freezing day	Winter temperature	Temperature of snow days
This study area	7.4 day	2.69 [cm]	113.3 day	1.79℃	-0.34℃
Average of whole country	18.9 day	-	89 day	-	-

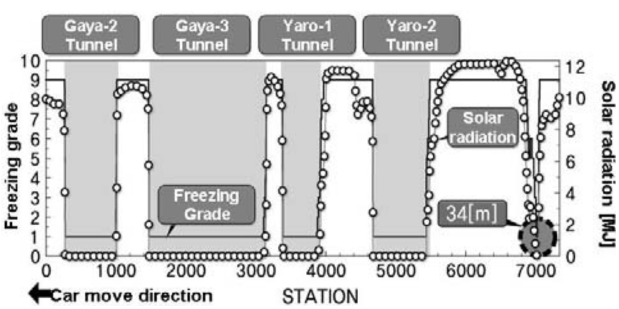
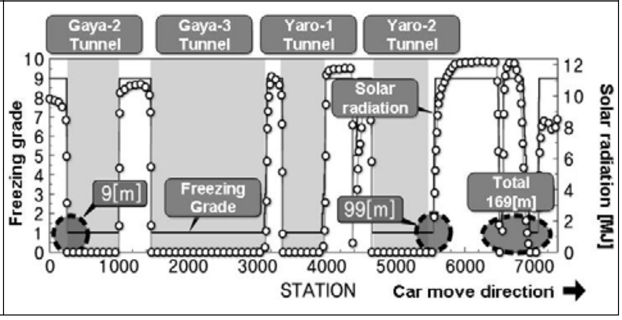
Table 14. Risk class of freezing

Type	1	2	3	4	5	6	7	8	9
Risk class	Ordinary freezing	danger of freezing at daytime		Possibility of freezing at daytime		Freezing at nighttime and heavy snow			Safety
Solar radiation [MJ]	0.18	0.367	1.117	1.863	2.980	3.724	4.469	5.587	~
Safety management	treatment to prevent freezing	treatment to prevent freezing Warning sign +snow-removing equipment		priority snow-removing work Warning sign		priority snow-removing work			generally snow-removing work

Accordingly this study analyze shadow section by SS3D (Solar Space 3D) program in the section of this study. Variation of sunshine circumstance is analyzed by simulating sun's orbit on 3-dimensional land and structure and this study analyze by compounding elements of sun's orbit, the upper part of land and structure, solar radiation, heat transfer on land etc.

Result of numerical analysis indicates that ordinary freezing section which has below solar radiation 0.18[MJ] is 9m from Gaya-2 tunnel entrance and 99m from Yaro-2 tunnel exit. And other sections don't have high danger of freezing as Risk class of freezing (Table 15)

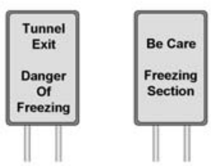
Table 15. Result of danger of freezing section

To Gwangju	To Daegu
	

4.3 Plan of safety facility as result of freezing dangerous section

Safety facility which can be applied in freezing dangerous section is divided safety facility type (I) which can remove before freezing and safety facility type (II) which gives information about freezing section and reduce possibility of freezing. The plan of safety facility shall take into consider freezing danger grade, economic feasibility and efficiency. Safety facility shall be reviewed through simulation or other method of quantitative analysis reflecting weather's feature.

Table 16. Safety facility

Type		Picture	Process of operation	Remark
I	heating-wire type		•alloy line of copper, nickel and etc make heat by electric resistance and it make snow melting.	•Easy construction •cost is cheaper than other type •maintenance is difficult
	nozzle spray type		•The method of protecting freezing by spray melting solvent through spray nozzle in storing tank which is installed at road side.	•Easy construction •Maintenance cost is low-priced •Fist construction cost is high-priced
II	Grooving		•Enhance skid resistance at having low resistance spot so that car can be reduced braking distance.	-
	Chest of snow-removing work		•When snow-removing work isn't easy at winter, it help melting snow and reducing car sliding on the road.	-
	provide information of dangerous section		•install traffic safety sign for driver to percept dangerous section when enter the dangerous section and to plan safety driving.	

The result of analyzing freezing dangerous section is that Yaro-2 tunnel has Ordinary freezing section 99m from tunnel exit so it's section ensure skid resistance by grooving and chest of snow-

removing work, and Gaya-2 tunnel dangerous section ensure skid resistance by installing chest of snow-removing work at Gaya-2 tunnel entrance

5. Evaluation of the direct sunray effect

5.1 General

The direct sunray effect means to occur glare phenomenon when driver's eyes encounter the direct sunray by moving the car. The driver going through tunnel has more chance to encounter the direct sunray at the daytime because illuminance and brilliance between interior and exterior tunnel has a wide gap. Furthermore in case of a driver who isn’t adequate to adapt to changed condition due to insufficient information, driver has more risk of accident than others.

Consequently, when a continual tunnel planed, proper illumination is planed at tunnel boundary section, interior section, mitigation section and exiting section, considering driver's safety and circumstance in accordance with a sudden brightness change at tunnel entrance and exit. In addition, a safety facility : an example is installing canopy, is a good counter plan of the glare disability by difference between driver’s visual angle and sunray’s incident angel.

5.2 The evaluation result of the direct sunray effect analysis

This study focuses on dangerousness analysis of occurring the glare disability difference between driver's visual angle and sun's incident angle when driver passes tunnel.

The car exiting tunnel, the most important element is various sun's orbit according to driver's sight. If other conditions are same, sun's orbit has constant pattern (Table 17) every same day, so predicted analysis has high reliability about future condition. Driver's visual angle considering sun's altitude and azimuth at each season and hour and shadow condition are considered. In combination considering them, the analysis was done by Ray Tracing Method of SS3D(Solar Space 3D)

As result of analysis, refer to the sunray risk grade (Table 18), Yaro-2 tunnel's exit which is positioning north-east to Daegu has relatively high risk and the direct sunray effect is occurred throughout the year in spring, summer and autumn (Table 19)

Driver's visual angle and sun's incident angle in spring and autumn is under 10°(the direct sunray grade is danger), so this case is concluded that driver's glare effect is high when driver comes out of the tunnel.

When sun's incident angle is small, it has high possibility that handling a car become difficult, so installing safety facility like canopy and etc is needed.

The analysis indicates that Yaro-1 tunnel exit to Daegu has 20 minutes of danger time in winter and 90 minutes of trouble time in spring and autumn. Yaro-2 tunnel exit to Daegu has 40 minutes of danger time in spring and 100 minutes of trouble time in winter.

Table 17. Sun's orbit

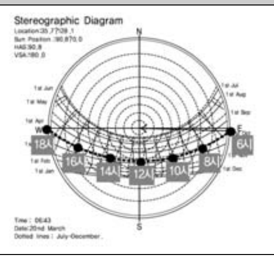
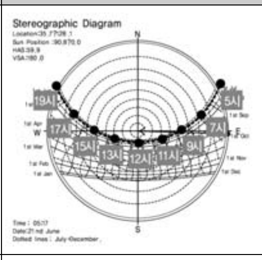
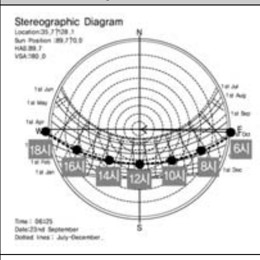
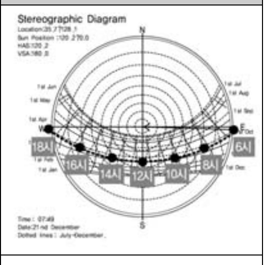
Type	The spring equinox	The summer solstice	The autumnal equinox	The winter solstice
sun's orbit				
Incident Angle	90°~ 268°	60°~ 298°	91°~ 269°	119°~ 240°
Altitude	0°~ 53°	0°~ 76°	0°~ 53°	0°~ 30°
Sunshine time	06:31 ~ 18:38	05:11 ~ 19:46	06:16 ~ 18:23	07:33 ~ 17:17

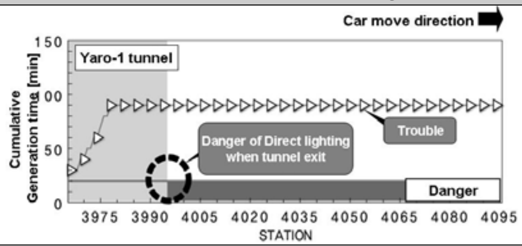
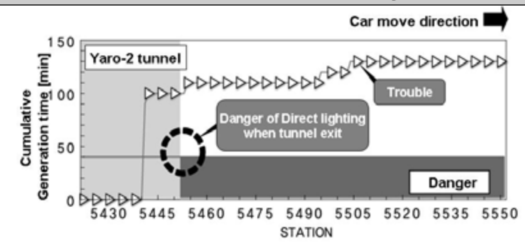
Table 18. The sunray direct risk grade

An angle of incidence	Grade	Conditions	Management plan
Above 30°	Safety	·No direct sunray effect	-
10° ~ 30°	trouble	·Possibility of whiting ·trouble identification of a visual field	Warning Sign
Under 10°	danger	·Disability glare ·Impossible identification of a visual field	Canopy / Warning Sign

Table 19. The result of the direct sunray effect risk

Period [min]		Advance into Gaya-2 tunnel		Advance into Gaya-3 tunnel		Advance into Yaro-1 tunnel		Advance into Yaro-2 tunnel	
		To Gwangju	To Daegu	To Gwangju	To Daegu	To Gwangju	To Daegu	To Gwangju	To Daegu
Spring	Danger	-	-	-	-	-	-	-	40
	Trouble	50	100	20	90	-	90	-	80
Summer	Danger	-	-	-	-	-	-	40	-
	Trouble	110	-	110	-	70	-	90	100
Autumn	Danger	-	-	-	-	-	-	-	30
	Trouble	50	100	20	90	-	90	-	90
Winter	Danger	-	-	-	10	-	20	-	-
	Trouble	-	30	-	90	-	90	-	-
Danger days for a year		-	-	-	10	-	20	40	70

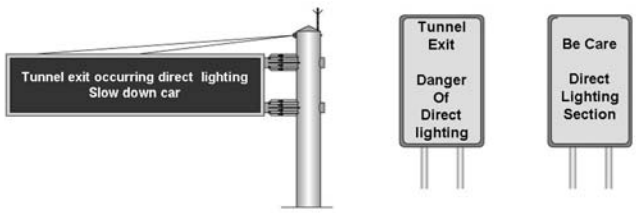
Table 20. Detail analysis of the direct sunray effect

<table>
<tr><th>Type</th><th>Yaro-1 tunnel to Daegu</th><th>Yaro2 tunnel to Daegu</th></tr>
<tr><td>Result of analysis</td><td>
</td><td>
</td></tr>
</table>

5.3 Safety facility plan for risk of the direct sunray

An example is a canopy for safety facility (Table 21) to deal with risk of the direct sunray. Otherwise, And there are VMS(Variable Message Signs) and warning sign etc which gives drivers information before the driving dangerous section. To evaluate the direct sunray effect in this study section conclude that Yaro-2 tunnel has the most many days, 70 danger days per year. After analyzing economic and efficiency assessment, exit of Yaro-2 tunnel was planed to install a canopy. Other tunnels are planed to install VMS and warning sign etc for ensuring driver's safety.

Table 21. Safety facility

<table>
<tr><th>Type</th><th>Installing canopy</th><th>Provide danger information (VMS / Warning sign)</th></tr>
<tr><td>Appearance</td><td></td><td>
</td></tr>
</table>

6 Evaluation of fog effect

6.1 General

When driving in the fog, driver has narrow field of vision. Due to restrict visual range, a driver has risks. Moreover when driver suddenly meet dense fog, driver's visual field is far smaller than driver's actual visual field.

When dense fog 1.8~2.4m height, in case of the car which have high height like truck, a driver can't percept the preceding passenger car which have low height and it make dangerous situation. Thus, the risk rises because the accident possibility gets higher because of a broken car or going slow car for fog. So we need to deal with above problem.

6.2 Result of analysis

Table 22. Result of analyzing local fog feature

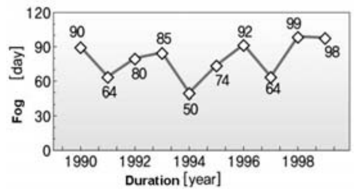
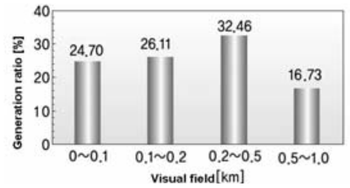
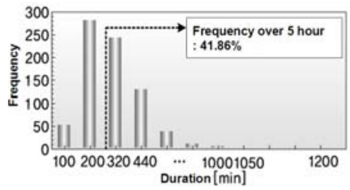
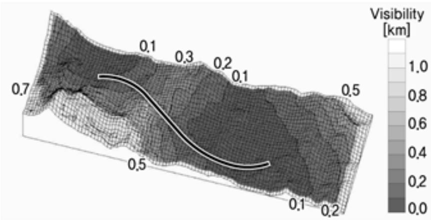
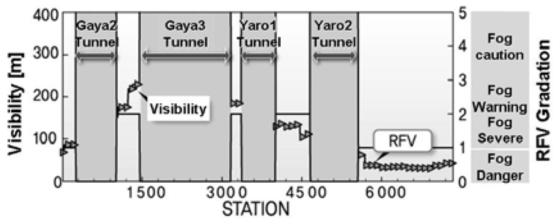
<table>
<tr><th>Type</th><th>Fog days in each year</th><th>distribution of visibility in fog</th><th>Frequency of fog duration</th></tr>
<tr><td rowspan="2">Result of analysis</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>·Maximum: 99 days(1998)
·Average: 80 days</td><td>·Below 0.2[km]: 50.81[%]</td><td>·Over 5 hours
duration: 41.86[%]</td></tr>
</table>

Table 23. Result of fog risk

<table>
<tr><th>Visibility distribution of analysis section</th><th>Result of RFV(Risk of Fog Visibility) grade</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Result of analyzing local fog features indicates that the average fog days is 79.6 days which is 31 days higher than the average in the whole country, and the ratio of dense fog below 0.2km visibility is 50.81% which is high. Above analysis shows that the local area has high fog effect.

Fog sensitively responds sensitive to geographical conditions, temperature, moist, direction of wind, velocity of wind, solar radiation and so on. Its sensitive reaction makes limit to actually simulate generation and lifting. Therefore, the study focuses on pattern of visibility reduction by of analyzing fog diffusion generated in the source of lake or river surrounding this study section. The study derives visibility reduction by numerical analysis and it makes risk grade by RFV(Risk of Fog Visibility) grade throughout the study area.

As result of analyzing the visibility reduction, the study indicates that all area is below RFV 2grade which has visibility of below 0.3km. This section is needed to install a safety facility to ensure driver's travelling safety, because RFV 2grade which has considerable visibility reduction means severe section fog.

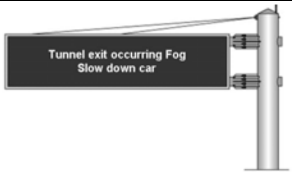
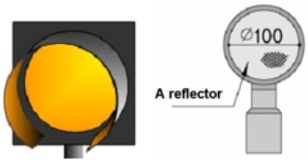
6.3 Safety facility plan for risk of fog

Safety plan for dealing with risk of fog to ensure driver's safety is divided in following 3 methods according to its effect.

- The positive method : fog removal
- Inducing safe driving by provide information of fog risk section
- Ensuring travelling line by guide driver's eye

Safety facility must be installed by considering visibility reduction by fog features for driving lane and geometrical feature. All analyzed section is below RFV 2 grade which has high risk of fog, so a safety facility must be installed to deal with fog. All analyzed section has VMS, fog lamps, delineator and chevron signs to ensure driver's travelling safety.

Table 24. Safety facility to deal with fog risk

Type	Fog removal	Fog risk alarm	Mark for driving lane
Type	Anti-fog system	VMS, Warning sign	fog lamps, delineator and chevron signs
Example			

7. Conclusion

Korea has many mountain areas. Therefore it is the trend to construct long and continual tunnel to be environment friendly and enhance level of service quality, so travelling safety is continually required at continual tunnel section. Accordingly, detail design of Damyang and Seongsan of the highway No. 12(Section No. 12) is selected as practical case to propose objective and quantitative method of road plan at continual tunnel section.

This study objectively analyze driver's behavior, visual trouble etc about projecting structure near tunnel like bridge etc, direct sunray effect and weather & climate at continual tunnel section. And classifies into grade which decided by estimating quantity of relevant analysis. Above steps is reflected to detail design, so dangerous elements are excluded and accidents are prevented by rational alignment reflected geographical features and suitable plan of safety facility in the dangerous sections. Objective of this study is deriving smooth traffic flow and driver's safe insurance plan through above steps.

Based on above steps, the result of this study is as follows

Considering function, economical efficiency, environment friendly and minimizing popular complaints etc through mountain area, the most suitable route was selected.
Its route occur downgrade continual tunnel, so drivers are exposed risk by physical and psychological elements, which are occurred by geometric feature, cross section's variation and approaching structures. And analysis indicate that the danger of car accidents is high at entrance and exit of tunnel because of freezing, direct sunray effect and fog etc by weather and climate feature. Consequently, this study intend to exclude the risk source of car accidents by improving vertical and horizontal alignment, widening tunnel entrance and exit section and planning bridge tower considering driver's visual field etc.

But if travelling safety can't be ensured because there are some alignment limits for reason of geographical features, this study calculate quantitative risk induced weather and climate and analyze dangerous sections to reduce risk. And driver's travelling safety is ensured by objectively suitable plan of safety facility at dangerous sections.

According to economic growth, future road construction aim to enhance user's mobility and level of service so many plans which have continual tunnel at mountainous area are occurred. Therefore its plans need to ensure driver's safety by inducing dangerous elements of location's condition and analyzing objectively scientifically.

Therefore, road plan method of this study is needed for more systematical and scientific development. And need continually to research about basic driver's reaction and behavior etc to geography and accumulate date about accidents at continual tunnel section etc to design road plan verified safety system based on more scientific and objective decision. Based on verified methods, the systematical standard is needed. And based on the systematical standard, road plan of continual tunnel section at mountainous area systematically, objectively and rationally ensure driver's safety.

REFERENCES

1. Chul OH. et al. Relationship between V/C and Accident Rate for Freeway Facility Sections (focused on Shingal-Ansan Freeway). Journal of Korean Society of Transportation Vol.17 No.2. 1999
2. Korea express corporation, Evaluation distance between tunnel and interchange and complement. Technique examine department. 2002
3. Korean Ministry of Land, Transport and Maritime Affairs. A rule of road's geometric and facility standard. 2003
4. Chul-Woong DO. The principles of Traffic engineering. 1998